TEACHWITHPORTALS™

Subject: Physics

Title: Man on the Moon!

Author: Cameron Pittman, Teacher

School / Organization, City and State / Province: Stratford STEM Magnet High School, Nashville, TN

Grade Level: 11-12

Standards Met:

Physics Standards

Conservation of Energy, Projectile Motion, Free Fall, Gravity

Next Generation Science Standards

HS.PS-FM Forces and Motion, performance standard (a) Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.

HS.PS-E Energy, performance standard (a) Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system.

Science and Engineering Practices: Planning and carrying out investigations, Analyzing and interpreting data, Using mathematics and computational thinking, Constructing explanations and designing solutions, Developing and using models.

ACT Standards

Interpretation of Data – Compare or combine data from a simple data presentation (20-23)

Scientific Investigation – Predict the results of an additional trial or measurement in an experiment (24-27)

Time Needed: 60 minutes

Objective(s): Students will recognize that mass has no effect on a falling object's velocity (ignoring friction)

Summary: This is a simple lab where students will be testing the effects of friction on falling objects. Students will demonstrate that friction, not mass, will slow objects in free fall. Students will derive the equation for the speed of an object in free fall using conservation of energy and show that mass is not a factor.

Vocabulary: Friction, Gravity, Mass, free fall, Conservation of Energy, Kinetic Energy, Potential Energy

Student Prerequisites: mass, friction, gravity, conservation of energy

Teacher Materials Needed: None

Student Materials Needed: hammers (or similarly heavy and dense objects), scrap paper, feathers, pennies

This lesson plan was developed with the idea that the educator understands physics and the basics of Portal 2. *The lesson itself should flow from an introduction, into a main lab activity, and then finish with follow up questions and a homework assignment. The* ***Introductory Activity*** *section starts with questions to ask students at the beginning of class or in the class prior. The* ***Implementation*** *section gives instructions to the instructor as to how to set up the main lab activity. The* ***Closing Activity*** *section lists questions for students after they complete the main lab activity. The* ***Homework*** *section suggests questions to assign as homework after the lab. The* ***Grading Advice*** *section gives answers to all of the questions in the* ***Introductory Activity***, ***Implementation***, ***Closing Activity***, *and* ***Homework*** *sections. I'm always looking for better lessons or ideas. If you have any questions or comments, please contact me at: cameron *dot* w *dot* pittman *at* gmail *dot* com.*

Introductory Activity:

1. A mischievous student is standing on the roof of Stratford STEM Magnet High School holding pennies and a hammer. He's timing how long it takes for the pennies to hit the ground in order to perfectly drop the rock on someone's head. Mr. Meyers, his physics teacher, is walking below. If he assumes the rock will fall 10 times faster than the pennies because it's 10 times heavier, does he have a chance at dropping the rock on Mr. Meyers' head? Why, or why not? Ignore friction.
2. What properties of matter determine how fast an object will fall?
3. On Earth, a sheet of paper takes a few seconds to hit the ground. Why?
4. Let's pretend that the Earth just lost all of its air. Once again, you drop a sheet of paper to the ground. Will the paper fall faster or slower? Why?
5. On the Moon, Apollo 15 Astronaut Dave Scott dropped a hammer and feather at the same time. What do you think happened next? Why?
6. One of the key principles of physics is that energy is always conserved. An object with the potential to fall has gravitational potential energy and a moving object has kinetic energy. In the process of falling, all of an object's gravitational potential energy is converted to kinetic energy (and thermal energy, if friction is a concern). If
   $$PE = mgh \quad (1)$$
   and
   $$KE = \frac{1}{2}mv^2 \quad (2)$$
   where m is mass, g is the acceleration due to gravity, and v is velocity, we can learn a little more about falling. Set equation 1 equal to equation 2 and solve for v.
7. What happens to mass in the previous problem? What implications does that have for the rate at which objects fall?

Implementation:

- The goal of this lab is to build a map that allows students to drop two objects at the exact same time from the exact same height. Recommended that they fall at least 4 wall tiles.
- Big hint: use hard light bridges!
- Students will need to be able to clearly see which object hits the ground first.
- Instruct students to fill out the attached lab worksheet, which contains information on what objects should be dropped in each trial. There is a place for the student to write down which object hit the ground first when dropped at the same time. If no object clearly hits the ground first, students should write "TIE."

- Students will be creating objects with different masses and different coefficients of friction. You'll need to check with the teacher forum (http://forums.steampowered.com/forums/forumdisplay.php?f=1249) for info on how to do that.
- (IF POSSIBLE) Repeat trials with weaker gravity and stronger gravity.
- To change gravity, use the following console commands (recommend posting on board):
    - *sv_cheats 1* (only needed to use for first time changing gravity)
    - *sv_gravity ** (replace the * with a strength for gravity. Default: 600)
- (https://developer.valvesoftware.com/wiki/Developer_Console#Commands_and_variables for more info on the console)

Closing Activity:

1. Allow students to correct their answers to the introductory activity and discuss as a class.
2. Look at setups 1, 2, 3. Were your results surprising? Why or why not?
3. Look at setups 4, 5, 6. How does mass affect the rate at which the cubes fell?
4. Look at setups 7, 8, 9. How does the strength of friction affect the rate at which the cubes fell?
5. Rank the following factors from least to most important in determining how quickly objects fall.
    a. Friction
    b. Mass
    c. Gravity
    d. Color
6. Compare and contrast your results using different values for gravity. If gravity is increased, what happens to the way objects fall? If gravity is decreased, what happens to the way objects fall? Does changing the strength of gravity alter your answers to any of the trials on the lab worksheet? Why or why not?
7. If time allows, allow students to drop hammers, feathers, pennies, wads of paper, and sheets of paper in the classroom (you might want to take the hammers to a grassy area). Instruct students to drop different sized objects at the same time. Ask them to compare the way paper drops when it is crumpled in comparison to it as a flat sheet.

Homework:

1. Why do feathers fall slower than hammers on Earth? What would have to happen to the Earth to make feathers fall as quickly as hammers?
2. In the absence of friction, which of the following have no influence on the way objects fall? Mass, gravity, weight, shape?
3. You and a friend are about to go bungy jumping in New Zealand. Your friend tells you that because he weighs more, he will fall faster and will enjoy the fall more. What do you have to say to your friend?
4. Chell, who has a mass of 60 kg (and is definitely not fat, no matter what GLaDOS says), is standing at a height of 10 units above the ground. Inside Aperture, gravity is set to accelerate objects downward at 4.7 units/s^2. Assume no friction.
    a. What will her velocity be when she hits the ground.
    b. You received extra information in this problem's introduction. What was it, and why was it unnecessary?

Grading Advice:

Introductory Activity:

1. No! They'll miss Mr. Meyers' head. Pennies do not fall 10 times faster than rocks because all objects fall at the same rate. While pennies and rocks will be affected by friction differently, the differences are much too small to show up in a drop off a high school building. In order to hit Mr. Meyers, the mischievous student should have used the timing he learned using pennies for the rock.
2. Gravity, friction.
3. The sheet of paper presents a very large surface area to be slowed by air resistance, while the paper ball presents a much smaller surface area and is not slowed nearly as much.
4. Both objects reach the ground at the same time because all objects fall at the same rate in the absence of friction.
5. They hit the ground at the same time. No air means the feather was not slowed by air resistance and was free to fall at the same rate as the hammer.
6. $mgh = \frac{1}{2}mv^2$ (3)

   m cancels out on both sides

   $gh = \frac{1}{2}v^2$ (4)

   $2gh = v^2$ (5)

   $\sqrt{2gh} = v$ (6)
7. If mass is not a factor for the velocity of falling objects, all objects should fall at the same rate (ignoring friction).

Closing Activity:

1. See above.
2. Hopefully not because identical objects should fall identically.
3. Mass itself has no effect.
4. The greater the friction, the slower the fall.
5. Color, Mass, Friction, Gravity
6. If gravity is stronger, objects will fall quicker, and vice versa. No, changing gravity should not change answers to any of the worksheet questions because both objects should be affected by gravity in the same way.

Homework:

1. Feathers feel a stronger force of friction because of their large surface area. Earth would need to lose all of its air in order for feathers to fall as quickly as hammers.
2. Mass, weight, and shape do not affect the rate at which objects fall without friction.
3. Your friend is wrong because mass has no effect on the rate at which objects fall. However, because the two of you are falling through air, you will feel friction. Your weight and the amount of surface area your body presents in the direction of your fall will affect the rate at which you fall. But it's pretty safe to say that any differences will be negligible and the two of you will fall at effectively the same rate.
4. Using equation 6, v = 9.7 u/s.

Additional Activities:

- Try dropping totally different objects or combinations of objects.
- Repeat as many experiments as possible in the real world. Students could easily drop masses of different sizes and shapes to replicate the different kinds of cubes found in the game.

TEACHWITHPORTALS™

Data Collection Worksheet – Man on the Moon!

You need to build a level that lets you drop two objects at the exact same time! Which one hits the ground first in the following scenarios?

Setup 1: Weighted vs Weighted

Winner? _____

Setup 2: Weighted vs Companion

Winner? _____

Setup 3: Weighted vs Turret

Winner? _____

Setup 4: Heavy Weighted vs Normal Weighted

Winner? _____

Setup 5: Heavy Weighted vs Light Weighted

Winner? _____

Setup 6: Normal Weighted vs Light Weighted

Winner? _____

Setup 7: Normal Weighted vs Low Friction Companion

Winner? _____

Setup 8: Normal Weighted vs High Friction Reflector

Winner? _____

Setup 9: Low Friction Companion vs High Friction Reflector

Winner? _____

Setup 10: Normal Weighted vs Light Frankencube

Winner? _____

Setup 11: Heavy Weighted vs High Friction Frankencube

Winner? _____

APERTURE LABORATORIES